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REDUCTION AND ANALYSIS OF ROCKET-BORNE AND BALLOON-BORNE SENSOR DATA

Paul F. Hilton

Systems and Applied Sciences Corporation
6811 Kenilworth Avenue
Riverdale, Maryland 20840

15 February 1981

Scientific Report No. 1

Approved for public release; distribution unlimited

AIR FORCE GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
HANSCOM AFB, MASSACHUSETTS 01731

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This report discusses the analysis and reduction of digitized data transmitted from probes flown on research balloons and on research rockets in the 50 - 500 km altitude range. The nature of the data transmission allows a standard procedure to be used, regardless of the experiment. This report details this standard approach and describes one experiment as an example.

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[illegible]

FOREWORD

This is the first annual technical report prepared and submitted by Systems and Applied Sciences Corporation under Contract F19628-80-C-0058. The report discusses the development of analytical techniques, and their implementation through computer routines, for the reduction and analysis of digitized data transmitted from sensors flown on research balloons and on research rockets in the 50 - 500 km altitude range. The data transmission systems employed permit the use of a standard procedure, regardless of the experiment flown. This report details that standard procedure and gives an example of one experiment.

Work was performed for the Analysis and Simulation Section (SUWA), Computation Branch, Office of Research Services, Air Force Geophysics Laboratory, Hanscom AFB, MA 01731.

SASC technical personnel employed on the contract were:

Paul F. Hilton, M.S., Principal Investigator
Charles F. Ivaldi, Jr., B.S., Programmer
Barry A. Mareiro, Jr., Junior Programmer
Stephen C. Phillips, Junior Programmer.

Program management was provided by Alan M. Gerlach, Ph.D.

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A. INTRODUCTION

The Analysis and Simulation Section, Computation Branch, Office of Research Services, Air Force Geophysics Laboratory, provides a wide range of technical support to in-house scientists in such areas as statistical and numerical analysis, computer simulation, and reduction and analysis of atmospheric and near-earth space environmental data. The major efforts are in those areas of geophysical research which utilize data transmitted from sensors flown on research balloons and rockets. The responsibility of Systems and Applied Sciences Corporation (SASC) is to provide support, not available from in-house sources, in the reduction and analysis of rocket- and balloon-borne sensor data.

Reduction of scientific data requires a wide variety of analytical methodologies, such as numerical techniques, including averaging, smoothing, and filtering of data; and the use of polynomial and Fourier approximations to model the data. Generally, the analysis is carried out on the AFGL CDC 6600 computer system. Software development as required for this contractual effort is the responsibility of SASC technical personnel; occasionally, existing routines are obtained from the AFGL computer system library.

The refined scientific data are correlated with trajectory and attitude information to provide space-time loci for the data points, and are displayed according to the specifications of the experimenter. Display methods include 2-dimensional, 3-dimensional, and contour plots, drawn with a pen-and-ink drum plotter, microfiche, or Tektronix.

The various research areas which SASC supports may be grouped into two major categories: particles, plasmas, and fields in the ionosphere and magnetosphere; and optical radiations (infrared, visible, ultraviolet) from auroral and other natural atmospheric sources, and from man-made sources. Instruments flown characteristically include radiometers, photometers, circular variable spectrometers, electrostatic analyzers, particle counters, electron spectrometers, energy deposition scintillators, and plasma frequency probes.

By means of these kinds of instruments and other sensors, experiments are carried out to meet a wide range of scientific objectives. For example, radiometers are designed for measuring selected auroral emissions in the infrared region of the spectrum, while photometers are used for measurement of visible and ultraviolet emissions. Particle counters provide quantity and low resolution energy measurements of energetic electrons within a predetermined field of view. With the aid of plasma frequency probes, electron densities and temperatures can be determined by resonant frequency techniques.

Although there are many areas of research, there is generally one data reduction and analysis methodology, which consists of four discrete steps: (1) vehicle profiles, (2) telemetry data with standard processing, (3) merging of trajectory and attitude data tapes, and (4) standard reduction and display. The next section will describe the standardized data processing system and the interactions between SUWA and SASC.

B. PROCESSING SYSTEM FOR ROCKET- AND BALLOON-BORNE EXPERIMENT DATA

No two experiments, or even two sensors from the same experiment, are processed in exactly the same way. However, the processing of any set of experiment data does follow a series of common steps. This section describes the general methodology used by SASC to reduce and process data, regardless of the specific nature of the sensor.

Of primary importance in the successful processing of experiment data is a thorough understanding of the purpose of the experiment, form of the data, intermediate stages in the processing stream, anticipated results, and formats for data presentation. Discussion between SUWA and SASC of the processing details often eliminates delays and makes possible a flexible system design.

Flexibility is of extreme importance because the processing is in many cases iterative, with modifications at each step. At the task definition stage, the researcher may not be able to anticipate the full extent of the processing required. Analysis of intermediate outputs may be necessary before the next stage of processing can be defined. Consequently, algorithms must be developed and the corresponding software designed to facilitate implementation of the latest modifications.

The three standard pre-processing information inputs are the analog strip chart, Digital Work Request, and Rocket Data Analysis Information. The analog strip chart is generated at the rocket launch site or by the Decommutation Section of the AFGL Computation Branch. The strip chart provides the experimenter with evidence of the success or failure of the mission. It gives the data processor information on timing or noise problems in the data. Periods of extensive noise, which requires special filtering, can be easily identified on the strip chart.

Figure 1 is an example of a strip chart of pre-flight calibrations, showing four voltage channels (odd numbers) and four current channels (even numbers). The signal is in telemetry volts, ranging from a lower band edge of zero volts (top of each plot) to an upper band edge of five volts. In the calibration stage the signal is stepped 0, 1, 2, 2.5, 3, 4, 5 volts and then back to zero. Figure 2, an example of in-flight data, provides the analyst with the opportunity to scan the transmitted data for any instrument problems.

The Digital Work Request (Figure 3) contains information about the packed data that are to be processed. For example, the Figure 3 request form shows that there are two files on tape R898 and there are eight channels (IRIG's 13 - 6). The short time on file 1 (05:45:13 to 05:45:31) indicates that it is a calibration file. Other information contained in the Digital Work Request includes rocket identification, launch date, sampling rate, start and stop times of each file, and data frame format.

The Rocket Data Analysis Information sheet contains a description of the experiment and analysis required, calibrations of telemetry volts to engineering units, launch date and time, vehicle number and type, digital tape format, and requested items such as listings, tapes, and plots. Figure 4 is an example of page one of the Rocket Data Analysis Information. Sometimes, the project scientist will attach technical reports describing the instruments involved in the flight.

Along with the standard pre-processing inputs, SUWA provides SASC with the appropriate R-tape(s). This tape contains experiment data which were telemetered in real time to a ground recording station. A typical rocket flight lasts between 300 and 500 seconds; the sampling rate is usually 1,000 samples per second (SPS) but may go to over 10,000 SPS. Data on the R-tape are in packed twelve-bit words. In order to process

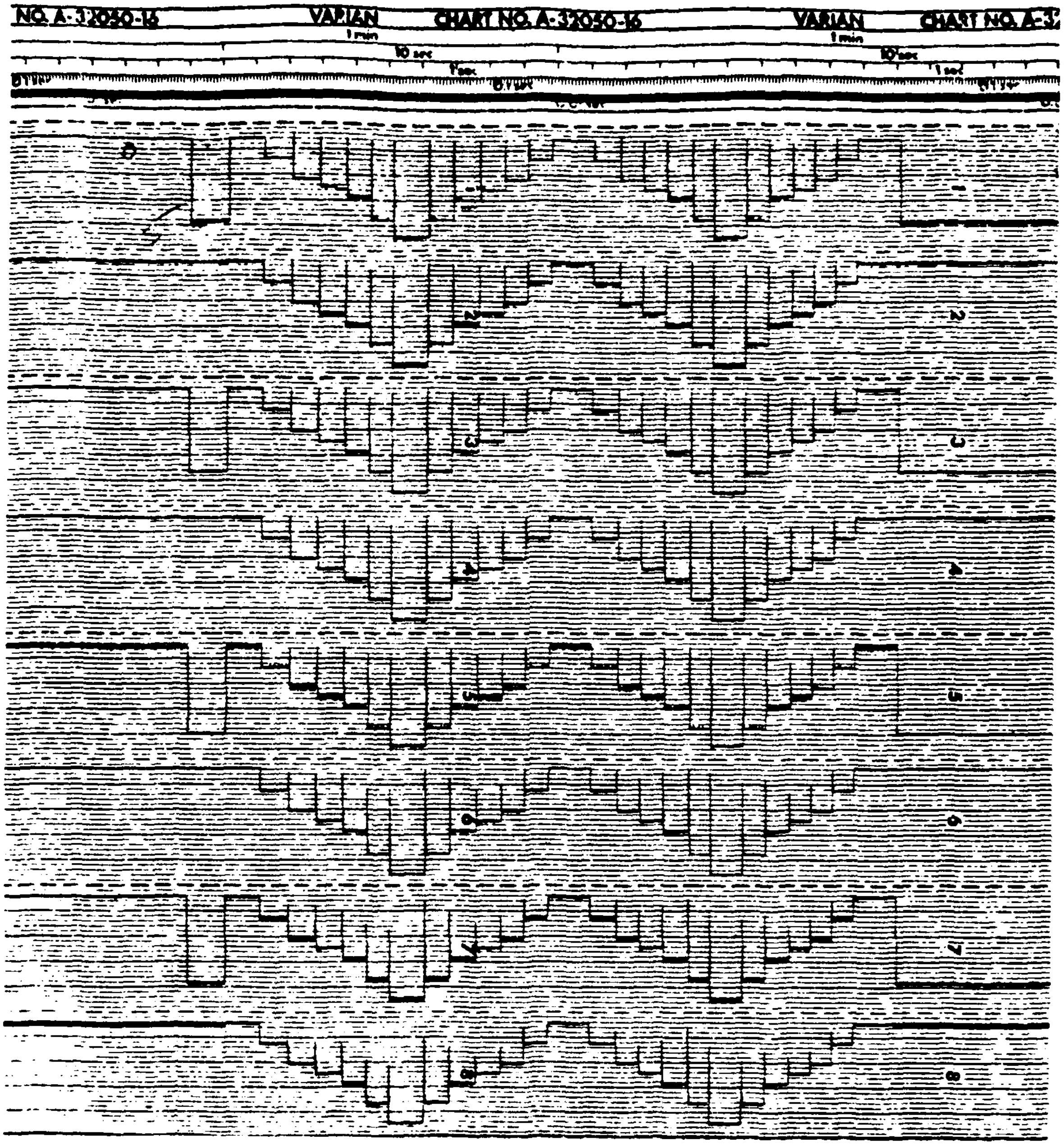

Figure 1. Strip chart of pre-flight calibration.

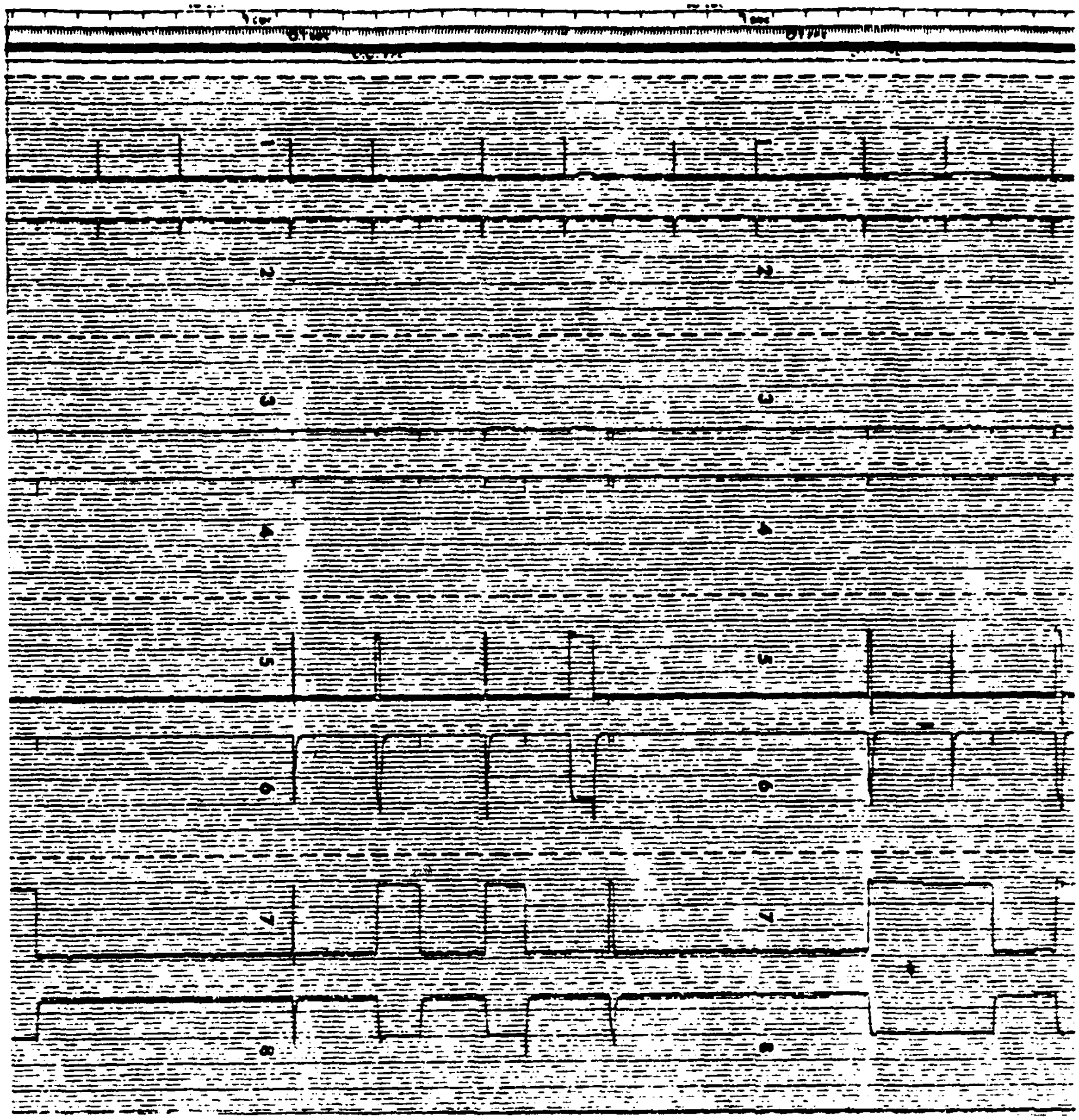

Figure 2. Strip chart of in-flight experiment data.

4/0 0546:40

DIGITAL WORK REQUEST

NUMBER: D 0590

REQUESTER (Name, Office Symbol, Phone No.)	PROJECT NUMBER	OPERATOR	DATE RECEIVED	DATE COMPLETED
SUWA McInerney/O'Neil X 4163	76701010			4/15/80

ANALOG TAPE IDENTIFICATION	RANGE	SETUP TIME	PROCESSING TIME	DATE REQUESTER NOTIFIED
A51.970 SDC Rec #2 Orig	PFRR			

LAUNCH DATE	START (HRS MIN SEC)	STOP (HRS MIN SEC)	PROCESSING SYSTEM
19 Oct 79	Listed below		☐ ASTRODATA ☒ HONEY WELL

OTHER SPECIFY	DIGITAL CALS: HIGH FREQUENCY	CENTER FREQUENCY	LOW FREQUENCY

DIGITAL TAPE NO.	ANALOG TAPE TRACK	FILE NO.	IRIG BAND	FREQ & DIRECT MODULATION	RADIO FREQ LINK	OUTPUT FILTER	SAMPLE RATE	DATA FRAME FORMAT	COMMUTATOR CHANNEL	COMMUTATOR RATE	CAL SEG 0%	CAL SEG 100%
590	7	1			4		8K Tot	MUX IRIG BANDS LISTED				
	7	2			4		" "					

R 848

REMARKS

IRIG 13,12,11,10,9,8,7,6

Frame = wst + 8 Data Samples

File 1: 0545:13 - 0545:31

2: 0547:40 - 0553:50

FILE 1

REC 142
START 292/05:45:13:000
STØP 292/05:45:31:047

FILE 2
REC 2892
START 292/05:47:40:000
STØP 292/05:53:50:069

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Figure 3. Digital Work Request.

Problem No. 3045
Project No. 76701010

ROCKET DATA ANALYSIS INFORMATION

EXPERIMENTER: Robert R. O'Neil

EXPERIMENT TITLE: EXCEDE - SPECTRAL: ELECTRON ACCELERATOR

LAUNCH SITE: POKER FLAT, ALASKA

LAUNCH DATE: 19 October 1979

LAUNCH TIME: 05:46:40 AOS: File 1: 05:45:13 / File 2: 05:47:40 LOS: 05:45:31 / 05:53:50

VEHICLE NO: A51.970 TYPE: TALOS-CASTOR

LINK FREQ: 2289.5 MHz

SUBCARRIER ASSIGNMENTS: IRIG 13, 12, 11, 10, 9, 8, 7, 6

TYPE OF DATA: PAM ____ FRAME SIZE ____

PCM ____ FRAME SIZE ____

FM X DIGITIZATION RATE 1 HHz/ Channel

PAM OR PCM CAL POINTS ____, ____

____, ____

FM INFLIGHT CALS: YES ____ NO X

PRELAUNCH CAL. DATA: YES X NO ____ File 1 05:45:13 - 05:45:31

ASPECT REQUIREMENTS: Yes - Separate Request

SPECIAL REQUIREMENTS: Accelerator performance to be merged with other EXCEDE Measurements (sensors), aspect, trajectory

		Start	Stop
REQUIRED START TIME:	File 1	05:45:13 -	05:45:31
STOP TIME:	File 2	05:47:40	05:53:50

Figure 4. Rocket Data Analysis Information.

these data on the CDC 6600 computer, the R-tape is unpacked into 60-bit CDC-compatible floating point words. Unpacking is accomplished by using a standardized software routine designated DQ for frequency modulated (FM) data. When the data are pulse code modulated (PCM) a standard routine HON316 is utilized.

Once the data are unpacked, quality checks are performed on the output. SASC uses software which will flag any two consecutive sampling times which are separated by a time greater than the sampling rate, or any step backwards in time. Time jumps generally come in pairs; that is, a time jump backwards is usually matched in magnitude by a forward time jump. This problem results from the software used to generate the R-tape and can usually be corrected by the analyst. However, occasionally the magnitude of the backward jump does not equal the forward jump. It may then be necessary to develop an algorithm to smooth the times or even to create a new R-tape. When the timing problems have been resolved, the data are put on tape in an irreducible form and the specified processing begins.

The unpacked data tape, without any timing problems, is the primary data base. The information on this tape is usually in counts which can later be translated into telemetry volts and subsequently into engineering units. Since the R-tape is returned to the archives, the irreducible data tape serves as the primary source of experiment data and remains as a point of origin if problems are encountered downstream in the data reduction.

If the equation which converts counts to telemetry volts is known, a new data base may be created immediately. However, if the calibration is not known, it is necessary to list data in the vicinity of the in-flight calibrations. The on-board telemetry system is able to send a step-pulsed signal (0 - 2.5 - 5.0 volts). The normal lower band edge is represented by a count value of -1638, which corresponds to zero telemetry volts, and the normal upper band edge has a count of 1638, which translates into five volts. The analyst averages the values at the upper and lower band edges and also at the middle of the band, 2.5 volts (zero counts). Usually there is a slight shift in the calibration scale, on the order of 70 counts. A linear equation is derived from the sample listing and used to create a data base in telemetry volts. A sample listing of counts and corresponding telemetry volts is made and an analysis is done to check the validity of the derived calibration equation. In most cases a fine-tuning of the calibration equation will yield the appropriate telemetry voltages.[1]

When the Contract Manager is confident that the appropriate linear equation to convert counts into telemetry volts has been found, the data are ready to be changed into engineering units. The calibration equations used to give physical meaning to the count data received at the ground station are the result of work by the instrument technicians in their laboratory. The simplest equation is linear and valid for any value of the telemetry voltage. The more complicated equations involve logarithmic scales and may be valid only over a specified range.

Computer application of the calibration equation(s) to the raw data produces a data base on magnetic tape with information in units that have physical meaning. This data base is ready to be reduced, listed, or displayed. If the sampling rate is 1,000 SPS, it is usually sufficient to list the data at 20 - 50 SPS. This avoids unnecessary and extensive listings which take up computer time and space. If the experiment dictates a high sampling rate at specified times, it becomes a matter of retrieving the data from the original engineering unit tape.

Data may be displayed by pen-and-ink plots, microfiche, or Tektronix. Pen-and-ink plots are best suited for later reproduction in technical publications. Microfiche plots permit the most plots in the least amount of space. Copies of microfiche plots are suitable for publication purposes but yield to pen-and-ink because of slight distortions in the reproducing process. Plots which are copied directly from the Tektronix are useful in the preliminary stages of plotting the data, because the turn-around time is short.

Finally, after the data have been reduced, trajectory and attitude data are merged with the experiment data. Standard trajectory and attitude tapes are provided to SASC to create a final tape containing all the information. If listings or plots of the combined data are required, they are supplied.

C. DATA PROCESSING: FLIGHT B SPECTROMETER

Although there is a wide range of experiments at AFGL, the processing of rocket- and balloon-borne sensor data follows a series of common

[1]For a detailed study of telemetry systems the reader is encouraged to refer to Aerospace Telemetry, Vol. 1, edited by Harry L. Stiltz. Prentice-Hall Inc., Englewood Cliffs, New Jersey.

steps. This section describes the step-by-step process followed in an actual project.

Scientists at AFGL are conducting a series of experiments to obtain absolute values of the solar flux over a rising period of the eleven-year solar cycle. Measurements are made in the vacuum and near ultraviolet regions. Five rocket flights were made from May 1976 to September 1980, as listed in Table 1.

TABLE 1. FIVE ROCKET LAUNCHES - SPECTROMETER

FLIGHT	DATE	VEHICLE AND INSTRUMENTATION
A	May 18, 1976	Rocket - A03.410-1 Instrument - Rocket Spectrometer No. 61-I Wavelength range - 170 - 350 nm Number of spectrometers - 1
B	April 21, 1977	Rocket - A04.410-2 Instrument - Rocket Spectrometer No. 61-II Wavelength range - 170 - 350 nm Number of spectromters - 1
C	August 9, 1977	Rocket - A03.509.1 Instrument - Rocket Spectrometer No. 62-I Wavelength range - 130 - 180 nm; 170 - 350 nm Number of spectrometers - 2
D	September 19, 1978	Rocket - A04.711-1 Instrument - Rocket Spectrometer No. 62-II Wavelength range - 130 - 180 nm; 170 - 350 nm Number of spectrometers - 2
E	September 18, 1980	Rocket - A04.801(RS-61) Instrument - Rocket Spectrometer No. 62-III Wavelength range - 175 - 310 nm Number of spectrometers - 1

This section will cover Flight B.

At the initial meeting with the SUWA Contract Manager, SASC was given a copy of the Digital Work Request (Figure 5), which described the R-tape R730, and a detailed memorandum which outlined the data processing requirements.

DIGITAL WORK REQUEST

NUMBER: D 0597

REQUESTER (Name, Office Symbol, Phone No.): R. Swirbalus LKD 3316

PROJECT NUMBER: 66880601

OPERATOR:

DATE RECEIVED: 4/27/77

DATE COMPLETED: 4/29/77

ANALOG TAPE IDENTIFICATION: A04.410-2

RANGE:

SETUP TIME:

PROCESSING TIME:

DATE REQUESTER NOTIFIED:

LAUNCH DATE: 4/31/77

START: HRS MIN SEC

STOP: HRS MIN SEC

PROCESSING SYSTEM: ☐ ASTRODATA ☒ HONEY WELL

OTHER SPECIFY:

DIGITAL CALS: HIGH FREQUENCY

CENTER FREQUENCY

LOW FREQUENCY

DIGITAL TAPE NO.	ANALOG TAPE TRACK	FILE NO.	IRIG BAND	FREQ & DIRECT MODULATION	RADIO FREQ LINK	OUTPUT FILTER	SAMPLE RATE	DATA FRAME FORMAT	COMMUTATOR CHANNEL	COMMUTATOR RATE	CAL SEG 0%	CAL SEG 100%
597		1						Test Data 1658:15				
								1659:30				
		2						Flight Data 1702:00				
								1707:00				

REMARKS: Process best PCM data per attachment
Parker Station - Tape Trk 5 Best Data

PROCESSING WILL COMMENCE ON RECEIPT OF THIS VERIFICATION.

SIGNATURE: DATE:

AFGL FORM 10 AFSC-HANSCOM AFB MA

Figure 5. Digital Work Request for Flight B Spectrometer.

The raw telemetry data for each flight were generated by a solar-pointed spectrometer. The spectrometer admits light through a narrow entrance slit, separates the light according to wavelength by an optical grating, and focusses the image of the slit on the photosensitive surface of a detector which in turn produces an electrical signal proportional to the incident illumination. This detector signal, called photon count, is transmitted digitally in 4 BCD bits which range from 0000 to 9999. (On a logarithmic plot 0 is to be plotted as 1, (10^0), and hence a four-decade axis is required to cover the full range of data, namely, 10^0, 10^1, 10^2, 10^3.)

Wavelengths are selected by mechanical rotation of the optical grating. This rotation is transmitted through a gear train from a pulsed stepping motor, connected to an encoder. The encoder provides a 4-bit BCD number to telemetry to establish the wavelength at which the photon count data were recorded. The encoder does not have sufficient resolution to indicate the motion associated with one drive pulse, but rather increments once every 13 steps. The telemetry data will therefore show the same wavelength value 13 times for a sequence of data frames, although the wavelength has in fact changed. The standard time interval between frames is 4 ± 1 milliseconds.

The first step in the data analysis and reduction was to unpack the twelve-bit words into 60-bit CDC words. Tape R730 was unpacked onto tape CC0487 and returned to the AFGL tape archives. Tape CC0487 became the primary data source, arranged in digitized format. Figure 6 shows the bit construction of the words on CC0487. Each frame of data contains four words, including universal time of day in seconds, wavelength, and photon count. As an example, consider a word which has a zero fill for bits 60 to 17, and bits 16 to 1 look like:

Bit	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	0	1	0	0	0	0	0	1	0	0	1	1	0	1	0	1.

This word, when divided into four different values, each multiplied by an appropriate power of ten, yields:

$$5(10^0) + 3(10^1) + 1(10^2) + 4(10^3) = 4135.$$

The next step was to create a data base which allowed the analyst wide latitude in processing and reduced computer time. This new data base was created from CC0487 and put on tape CC3901. Each data frame con-

60 bit time of day (sec)	60 bit sync word	60 bit wavelength word	60 bit photon count word

Each has 16 bits, right justified, with a zero fill

WAVELENGTH WORD (bit 60 to 17 zero-filled)

$$\text{Bit}\ \overbrace{16\ 15\ 14\ 13}^{x10^{3}}\ \overbrace{12\ 11\ 10\ 9}^{x10^{2}}\ \overbrace{8\ 7\ 6\ 5}^{x10^{1}}\ \overbrace{4\ 3\ 2\ 1}^{x10^{0}}$$

PHOTON COUNT WORD (bit 60 to 17 zero-filled)

$$\text{Bit}\ \overbrace{16\ 15\ 14\ 13}^{x10^{3}}\ \overbrace{12\ 11\ 10\ 9}^{x10^{2}}\ \overbrace{8\ 7\ 6\ 5}^{x10^{1}}\ \overbrace{4\ 3\ 2\ 1}^{x10^{0}}$$

Figure 6. Bit construction of words.

sisted of universal time of day (HHMMSS), integer wavelength (angstroms), and integer photon count. A listing of these raw data was also created and delivered to the Contract Manager. Figure 7 is a sample of that listing.

As noted above, the mechanical arrangement of the instrument dictates 13 steps per wavelength and sampling at 4 ± 1 milliseconds. After tape CC3901 was created it was necessary to develop an algorithm which would flag all deviations from the instrumentation routine. The Contract Manager provided SASC with the time segments involved in the spectrometer scans, excluding the time when the filter is inserted. The data on CC3901 were checked for irregular wavelength and time intervals. All irregularities were identified by SASC and this information was supplied to the Contract Manager. Recommendations for adjusting the data base to correct for the irregularities were then given to SASC.

The changes to CC3901 were made and a complete data base with regular wavelength and time sampling was made on CC4521. A quality check of data changes was made and the entire data base was listed, in the format of Figure 7, and displayed on microfiche, as in Figure 8. At this point the data were correct, according to the sampling rate, but errors in the count rate caused by bit transmission difficulties had to be corrected.

Identification and correction of the transmission errors can be done by hand but is a time consuming process. An algorithm was developed as a result of several meetings of the SASC Principal Investigator, Contract Manager, and project representative. The full algorithm (see Section C.1) was carried out on the CDC 6600. The ensuing refined data base was listed with the bad data (in parentheses) replaced with corrected data (Figure 9) and put on tape CC1520.

At this point, 80 - 90% of the transmission errors had been identified and adjusted. The remaining 10 - 20% were identified by the project team and listed for SASC. Software was developed to modify the data base on CC1520. A final data base free of both sampling and transmission errors was made on CC1974, and a corresponding data list was given to the Contract Manager.

The next step will be to display the data on pen-and-ink plots. When the project is completed, SASC will deliver a final data tape and all software developed by SASC which is determined to be useful in the future.

PEDO FLIGHT B APRIL 21,1977

TIME (HHMMSS)	WAVELENGTH (ANGSTROM)	COUNT
17/ 3/ 9.136	1853	24
17/ 3/ 9.141	1853	27
17/ 3/ 9.145	1853	24
17/ 3/ 9.150	1853	25
17/ 3/ 9.154	1853	30
17/ 3/ 9.158	1853	24
17/ 3/ 9.163	1853	33
17/ 3/ 9.167	1853	31
17/ 3/ 9.172	1853	26
17/ 3/ 9.176	1853	28
17/ 3/ 9.181	1853	21
17/ 3/ 9.185	1853	33
17/ 3/ 9.190	1853	40
17/ 3/ 9.194	1854	38
17/ 3/ 9.199	1854	26
17/ 3/ 9.203	1854	38
17/ 3/ 9.208	1854	24
17/ 3/ 9.212	1854	27
17/ 3/ 9.217	1854	33
17/ 3/ 9.221	1854	35
17/ 3/ 9.225	1854	34
17/ 3/ 9.230	1854	34
17/ 3/ 9.234	1854	34
17/ 3/ 9.239	1854	35
17/ 3/ 9.243	1854	38
17/ 3/ 9.248	1854	42
17/ 3/ 9.252	1855	35
17/ 3/ 9.257	1855	29
17/ 3/ 9.261	1855	27
17/ 3/ 9.266	1855	23
17/ 3/ 9.270	1855	18
17/ 3/ 9.275	1855	26
17/ 3/ 9.279	1855	26
17/ 3/ 9.284	1855	31
17/ 3/ 9.288	1855	34
17/ 3/ 9.292	1855	30
17/ 3/ 9.297	1855	27
17/ 3/ 9.301	1855	33
17/ 3/ 9.306	1855	28
17/ 3/ 9.310	1856	38
17/ 3/ 9.315	1856	13
17/ 3/ 9.319	1856	34
17/ 3/ 9.324	1856	26
17/ 3/ 9.328	1856	34

Figure 7. First listing of Flight B data.

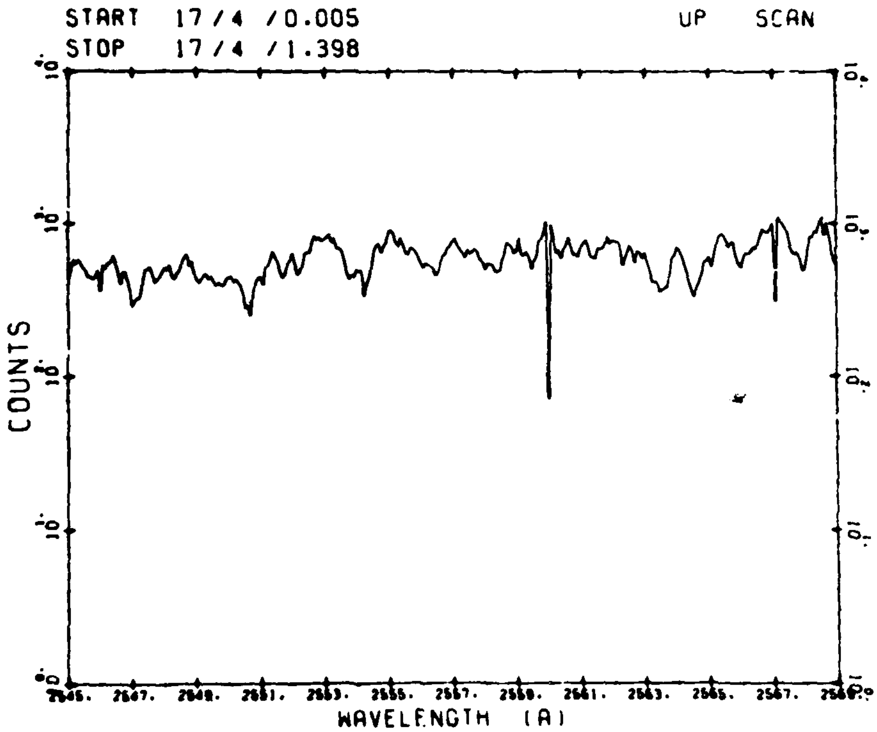

Figure 8. Sample of microfiche plot of Flight B data.

BEDO FLIGHT B APRIL 21,1977

TIME (HHMMSS)	WAVELENGTH (ANGSTROM)	COUNT	
17/ 3/ 9.136	1853	24	
17/ 3/ 9.141	1853	27	
17/ 3/ 9.145	1853	24	
17/ 3/ 9.150	1853	25	
17/ 3/ 9.154	1853	30	
17/ 3/ 9.158	1853	24	
17/ 3/ 9.163	1853	33	
17/ 3/ 9.167	1853	31	
17/ 3/ 9.172	1853	26	
17/ 3/ 9.176	1853	28	
17/ 3/ 9.181	1853	31	(21)
17/ 3/ 9.185	1853	33	
17/ 3/ 9.190	1853	40	
17/ 3/ 9.194	1854	38	
17/ 3/ 9.199	1854	26	
17/ 3/ 9.203	1854	38	
17/ 3/ 9.208	1854	24	
17/ 3/ 9.212	1854	27	
17/ 3/ 9.217	1854	33	
17/ 3/ 9.221	1854	35	
17/ 3/ 9.225	1854	34	
17/ 3/ 9.230	1854	34	
17/ 3/ 9.234	1854	34	
17/ 3/ 9.239	1854	35	
17/ 3/ 9.243	1854	38	
17/ 3/ 9.248	1854	42	
17/ 3/ 9.252	1855	35	
17/ 3/ 9.257	1855	29	
17/ 3/ 9.261	1855	27	
17/ 3/ 9.266	1855	23	
17/ 3/ 9.270	1855	18	
17/ 3/ 9.275	1855	26	
17/ 3/ 9.279	1855	26	
17/ 3/ 9.284	1855	31	
17/ 3/ 9.288	1855	34	
17/ 3/ 9.292	1855	30	
17/ 3/ 9.297	1855	27	
17/ 3/ 9.301	1855	33	
17/ 3/ 9.306	1855	38	
17/ 3/ 9.310	1856	38	
17/ 3/ 9.315	1856	37	(13)
17/ 3/ 9.319	1856	34	
17/ 3/ 9.324	1856	26	
17/ 3/ 9.328	1856	34	

Figure 9. Refined data listing of Flight B.

C.1. ERROR REMOVAL METHOD

Error Identification in the Data Set $n_1, n_2, \ldots. n_N$

1. Definitions:

   (a) n_a, n_b, n_c, n_d - four consecutive values in the data set.

   (b) $\Delta n_{ab} = n_a - n_b$

   $\Delta n_{bc} = n_b - n_c$

   $\Delta n_{cd} = n_c - n_d$

   (c) $\bar{n}_{ab} = \dfrac{n_a + n_b}{2}$

   $\bar{n}_{bc} = \dfrac{n_b + n_c}{2}$

   $\bar{n}_{cd} = \dfrac{n_c + n_d}{2}$

   (d) $G_B \equiv \dfrac{\Delta n_{ab}}{\bar{n}_{ab}} \cdot \dfrac{\Delta n_{bc}}{\bar{n}_{bc}}$

   $G_C \equiv \dfrac{\Delta n_{bc}}{\bar{n}_{bc}} \cdot \dfrac{\Delta n_{cd}}{\bar{n}_{cd}}$

   (e) $PCK \equiv \dfrac{1}{\sqrt{\bar{n}_{ac}}}$

2. Iterations :

   (a) The first pass through the data set makes changes to errors which are the result of transmission problems with the 1,000 word. An error is obtained when

   $$n_{ab} \cdot n_{bc} \leq - 10^6.$$

   (b) The second pass through will correct errors which may range from 2 to 880.

3. Identification of errors.

   (a) First pass: $n_{ab} \cdot n_{bc} \leq 10^{-6}$.

   (b) Second pass:

(i) Compute G_B. If $G_B \geq 0$ there is <u>no</u> error, but if $G_B < 0$ proceed to (ii).

(ii) Compute PCK. If $|G_B| <$ PCK there is no error; otherwise proceed to (iii).

(iii) Compute $|G_C|$. If $|G_B| > |G_C|$ the error is at b; otherwise, error is at c.

4. Correction of error. Consider three consecutive data points x_1, x_2, x_3 where the error has been identified at x_2.

(a) Compute average. $\quad AVE = \frac{(x_1 + x_3)}{2}$

(b) Compute the absolute difference between the error and AVE.

$$GLDIF = |x_2 - AVE|$$

(c) Calculate the difference between GLDIF and each factor. The first pass uses

FACTOR (j) j = 1,..,4 which are

1,000, 2,000, 4,000, 8,000 respectively.

A list of the 38 factors used for the second pass is included at the end of this section.

$$DIF\ (j) = |(GLDIF - FACTOR\ (j))|$$

(d) Determine which FACTOR (j) is the closest to zero.

(e) Determine whether FACTOR (j) is added to or subtracted from the error x_2.

5. Listing of data.

(a) Errors - The time and wavelength associated with the error, the error and its new value, and the measurement before and after the error are listed.

(b) Data - The final listing of the data shows time - wavelength - count. In the case where an error was discovered, the previous value of the count is provided in parentheses.

(c) Magnetic tape - The format of the words on magnetic tape is:

IHR, MIN, SEC, IWAVE, KOUNTN, KOUNTO, IFLG

where IHR, MIN, SEC are hours-minutes-seconds (of day)

IWAVE - wavelength

KOUNTN* - present value of count

KOUNTO - old value of count

IFLG - 0 indicates data frame is unaltered
       1 indicates data frame is changed.

*KOUNTN = KOUNTO in those frames where no error is found.

6. List of factors for second pass:

1.	2	20.	20
2.	4	21.	40
3.	8	22.	80
4.	10	23.	100
5.	12	24.	120
6.	14	25.	140
7.	18	26.	180
8.	20	27.	200
9.	22	28.	220
10.	24	29.	240
11.	28	30.	280
12.	40	31.	400
13.	42	32.	420
14.	44	33.	440
15.	48	34.	480
16.	82	35.	820
17.	84	36.	840
18.	86	37.	860
19.	88	38.	880